A Discussion on Life-Cycle Costs of Residential Photovoltaic Systems

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ABSTRACT
This paper discusses the characteristics and needed improvements/enhancements required for the expansion of the grid-tied residential power systems market. The purpose of the paper is to help establish a common understanding, between the technical community and the customers of the technology, of value and costs and what is required in the longer term for reaching the full potential of this application.

INTRODUCTION
The decision to invest in PV is based on a unique set of values depending on everything from improvement of the environment, to more personal involvement in energy production, to increased reliability, to energy value. In this paper, we will discuss many of the key technical and non-technical elements that affect values and the purchase of residential PV systems. The intent of the paper is to lay a foundation for common understanding of terms, an understanding that is required for the technology to be understood by all and the lack of which is currently a major barrier toward future expansion of the residential application. We will first look at the rationale commonly used to purchase such a system and combine them into a discussion regarding system value and costs.

The decision to purchase a PV system is affected by a number of issues including:

- What do customers want?
- What is the purchase price?
- Is there a product/system infrastructure available?
- What is required to own and maintain a system?

The following customer specific values and costs are at the heart of the discussion to improve acceptance of PV systems and include

- Enhanced quality (value)
- Training of installers and builders (cost)
- Development of a qualified database (cost)
- Improved building integration (value)
- Reduction in installed and recurring costs (cost)
- Expanded electric utility acceptance (value)
- Improved consumer education (value)

WHAT DO CUSTOMERS WANT?
The consumer buys many things that are seen as good investments because of their quality and because of the perceived benefit from them. While some of these reasons may change in the future, the primary benefits from PV today are substantial. First, the residential consumer can use PV to offset energy production from other more polluting technologies. PV systems can be placed on the roof of virtually any structure and therefore require no additional land space. PV, like solar thermal hot water collectors, can directly defer costs and increase self-reliance. These systems also require very little routine maintenance.

The size in watts of a residential, grid-tied PV system is not really a design issue, but one of preference and match with the structure and its orientation. There is little economy of scale difference between 500 W and 5 kW. So the homeowner can invest a relatively modest amount and still get some of the benefits. Because of the modularity, the consumer can either increase or move their system. This issue is, in fact, critical because of the re-roofing issue (discussed later).

WHAT IS THE PURCHASE PRICE?
It would be convenient to be able to combine all of these concepts and come up with a cost and a value for these types of systems on a national basis. There are many reasons why this is not straightforward. First, the economic value from the systems is, to a first approximation, a function of the amount of sunshine and the utility rates. These two commodities are different for each locale throughout the country, so the energy value will be different. Systems in areas with the high sunshine and highest utility rates will provide the highest energy value. If energy value were the sole reason for purchase, then sales would be limited to those areas of the country where the value is greatest.

Right now with an installed system efficiency of ~10%, 1 kW nameplate of PV modules will produce from about 1050 to 1650 kWh ac depending on location. At an average kWh price of $0.10, that means the total energy value ranges from a little over $100 in the first year to $165. Today's purchase prices vary from about $6.00/W to over $10/W installed. Industry/government goals for 3-5 years out put these costs at about half, and in ten years down to half again -- $1.50-$2.50/W. Even for a system that produced $165/year and cost $1.50/W, that corresponds to a breakeven in less than ten years if there are no recurring costs and if the energy production is constant. With these small economic benefits, it is likely that the decision to purchase a PV system, especially with energy storage, will be based more on self-reliance and environmental responsibility than on return of investment.

IS THERE A PRODUCT/SYSTEM INFRASTRUCUTRE AVAILABLE?

Today, most of the applications are added to existing structures. Several manufacturers have complete products (kits) that can be added to existing structures, from about 300 W up to several kW. This has resulted in reducing the indirect costs of marketing, distribution, and design. New construction and integration, especially in manufactured and other standard housing, represents a potentially large opportunity for PV in the future. On the other hand, custom design and integration in new housing could potentially decrease reliability and increase costs.

Customer satisfaction is based upon perceived value, a combination of benefits including cost and quality of systems. Quality is dependent upon the design, choice of components, installation, and maintenance. There is currently a dearth of training and certification programs that address the quality issues. The State of Florida has recently begun a certification program for installers through the Florida Solar Energy Center which is also developing a hardware and design approval process through the Florida PV Buildings Program. The manufacturers of packaged systems are attempting to build quality into their products by standardized design and by requiring specific training of its installers.

The weak link currently appears to be in the area of maintaining systems and components that are being sold with a stated 20 to 30 year lifetime. Only a limited number of electrical contractors currently have experience with PV systems. The solar industry and a few states are attempting to improve the situation through certification programs but this is an area that is only now developing. Once this situation is corrected, the cost of the after installation service will still need to be addressed.

WHAT IS REQUIRED TO OWN AND MAINTAIN A SYSTEM?

What can be expected from a PV system after installation? There are simply too few of these systems with a long enough history to answer this question with certainty. Let's look at some of the potential sources of problems.

Most of today's systems are placed over an existing roof structure. The time to replacement of the covering for flat roofs averages about 8 years in the southwestern part of the country, and most pitched roofs with standard materials are re-shingled perhaps every 12-15 years. Because these are the types of roofs that will potentially accommodate the largest numbers of PV systems, the labor cost of removal and re-attachment at least once during the 30-year life of the PV system is a starting point. The expected lifetime of the inverters even with maintenance is no greater than its internal components and has been estimated at 20 years. Thus, there will be the replacement cost of the inverter. Since the average American moves every 8 years, the 30-year concept has limited value until it is included in and increases the value of the structure upon resale. However, depending upon the age of the system and the roof, this could be a liability. We assume that in time the inverter will be a plug and play, but probably hard-wired except for ac modules and that the consumer will be able to perform this action, and that approach will save time and money. The re-roofing is a different matter for most.

Lifetime is a function of reliability and value. Once the cost (real and perceived) to maintain a system exceeds the value (real and perceived), the system is at end of life. Reliability is dependent upon the quality of the components, design, installation, and maintenance. Because the reliability and maintenance data on the residential application are so limited, we have no way to assess how the value of these systems will be impacted over time.

Another issue is general degradation of the system. This takes two forms, reversible and irreversible. An example of reversible degradation is soiling of the array which can reduce the output of an array in a rural or urban setting by as much as 25%. This is reversible because the array could be cleaned….at a cost. Irreversible electrical degradation is seen in almost all modules and represents about 0.5%/yr. A residential customer could ignore this small amount of degradation because it will represent only 50-100 kWh/ten years and the utility is providing back-up. However, it will diminish the energy value from the system.

A potentially large area of future maintenance will result from those systems where energy storage is added. While energy storage represents a very large potential benefit in terms of system availability, batteries do require routine maintenance, a special location, and replacement. Clearly there will be additional costs that must be defined including labor and capital.

SUMMARY

In summary, elements that are unique to the purchaser of future grid-tied residential systems have been discussed to develop a common understanding of the costs and values of these types of systems. Investment value is seen as secondary to self-reliance and environmental concerns. However, these benefits could easily be overshadowed by hassles caused by poor reliability and lack of affordable technical support once the system is installed.

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